# Nanoscale MOSFETs 2017 – Excercise 3

1. A. For a 2D conductor, with a small applied drain bias ΔV, show that the conductance can be written as

   $$G = \frac{I}{\Delta V} = qW\frac{N_{2D}}{2}\, v_T \frac{q}{kT}\, F_{-\frac{1}{2}}(\eta_F)$$

   B. Similarly, if the drain and source temperature difference is ΔT (<<T), show that there flows a current

   $$I = qW\frac{N_{2D}}{2} v_T \frac{1}{T}\left[\frac{3}{2}F_{1/2}(\eta_F) - \eta_F F_{-1/2}(\eta_F)\right]\Delta T = S_T \Delta T$$

   C. The Seebeck coefficient is defined as $S=S_T/G$, which corresponds to the induced open circuit voltage from an applied temperature difference $\Delta T$. Obtain $S$, and show that the Seebeck coefficient is independent of the bandstructure.

   Hint: $f(x_0 + \delta x) \approx f(x_0) + f'(x)_{x=x_0}\delta x$ and $\frac{d}{d\eta_F}F_j(\eta_F) = F_{j-1}(\eta_F)$.

2. For a FET limited by velocity saturation – which part of the channel sets the current level? How does this compare to a ballistic FET?
3. For an InAs 2DEG – calculate the thermal velocity. How high does $E_{FS}$-ε(0) need to be in order for the mean velocity to be 2× the thermal velocity?
4. The current of a single subband, 1D ballistic FET will be shown to be $I^+ = \frac{2q}{h}\int_0^\infty f_0 dE$. Similarly, the current of a 2D FET can be written as $I^+ = \frac{2q}{h}\int_0^\infty M(E) f_0 dE$, where M(E) is the so called number of modes. Determine M(E) for a 2D FET, and show that this corresponds to the number of 1D subbands below the energy E. A 2D FET can thus be seen as a large set of 1D transistors in parallel.